Arctic waters on the verge of changing?

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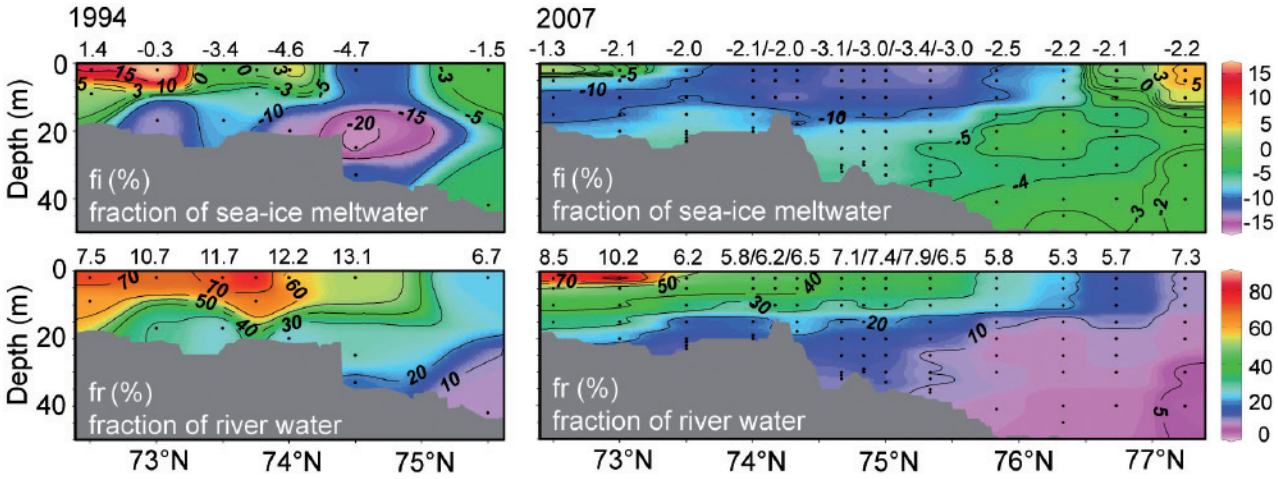
Satellite images document a decrease in Arctic ice cover in summer by 40% during the past 30 years. However, responsible processes and possible consequences of this decrease are little understood. The joint Russian-German project „Laptev Sea Polynya" is coordinated by IFM-GEOMAR and aims to ascertain the causes and consequences of climate change and its essential mechanisms in the Arctic. Now the project scientists revealed a changed water mass distribution in the Siberian Laptev Sea which might be of consequence for ice formation in the whole Arctic.

The project focuses on polynyas, open water areas between solid coastal ice and drift sea-ice of the open ocean. During winter large amounts of sea-ice form in these polynyas and consequently influence the water column. However, it is extremely difficult to observe this process in situ due to the severe winter conditions in this region. The use of stable oxygen isotopes of the water bypasses this problem because when the water freezes, the isotope ratio changes and these changes can be traced even a year later since the residence time of the water is larger than one year. In summer, when the Siberian coastal waters are ice-free, water samples can be taken relatively easily. Thus, it is possible to reveal how much sea-ice was formed in previous winters (Bauch et al., 1995).



The Laptev Sea Polynya during the field campaign in April 2008. Photo: H. Kassens, IFM-GEOMAR.

Although ice forms at the ocean surface, its isotopic traces are usually found at the bottom of the relatively shallow Laptev Sea because salt is released from the sea-ice and the resulting water is subsequently denser than the surrounding water mass, and sinks. However, measurements carried out in 2007 show a completely different picture: maxi-

Figure 1 (left): While the calculated fractions of river water (fr) show similar distributions in both years the fractions of sea-ice meltwater (fi) show a qualitatively inverse distribution in summer 2007 relative to 1994. The south to north oriented section along about 125 to 130°E shows maximal influence of sea-ice formation (negative fi) in the bottom layer in 1994 (left hand panels), while in 2007 (right hand panels) maximal influence is found in the surface layer. During 1994 at most stations only single samples were taken within the surface layer and bottom layer and the contour lines are mere interpolations between surface and bottom layer values, but due to the qualitative difference between the years, the lack of vertical resolution is not a problem. Inventory values in meters of river water and sea-ice meltwater are shown on top of sections. Figure taken from Bauch et al. (2010)

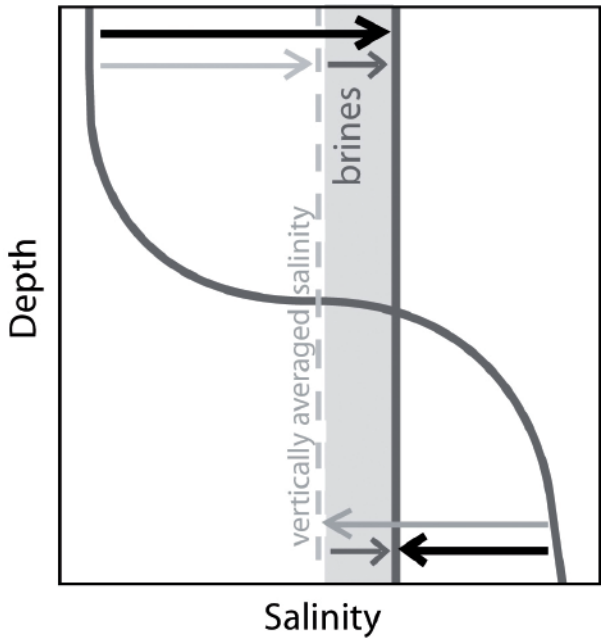


Figure 2: Primarily wind driven polynya events may decrease bottom salinities. The schematic drawing shows the typical low-salinity surface layer and the high-salinity bottom layer (gray curve) on the shelf transformed by mixing into a uniform profile at the average salinity of the initial water column (stippled gray line and light gray arrows) increased by the amount of brines released to the water column by sea-ice formation (dark gray arrows and gray line).

mal isotopic traces of sea-ice formation were found in the surface layer (see Fig. 1 upper panel). These findings contradict our conception of the stratification and distribution of water masses in this region.

A change in the mechanisms of ice formation in the coastal polynya might explain the unusual observations. In summer 2007 the Arctic Ocean experienced the lowest ice coverage on record and the observed polynyas in the Laptev Sea were unusually wide and persistent at the end of winter 2006/2007. This suggests a larger impact of sea-ice formation. But a polynya opening does not only trigger sea-ice formation and the unusually wide polynya opening also causes enhanced advection in the water column. Enhanced advection in 2007 can explain why the signal from sea-ice formation did not predominantly reach the bottom layer and also explains the salinity difference with less saline bottom water in summer 1994 compared to 2007 (not shown). Primarily wind driven polynya events may actually decrease salinities within the bottom layer, even though sea-ice formation adds overall brines to the water column (Fig. 2). If the inverted distribution in 2007 was not a singular event, but a long-term trend, the surface layer of the Arctic Ocean would receive saltier waters from the shelf (Bauch et al., 2010). This would result in the ice cover being less effectively isolated by the lower density gradient in the surface layer against the relatively warm and salty Atlantic layer present at about 200-300 m water depth in the whole Arctic Ocean. This could accelerate the decrease in the Arctic ice cover.

Further research is of particular importance as the Arctic is a key area for investigating climate change. Because the data coverage will always remain patchy due to the severe climate conditions in the Arctic, important focus of the project at IFM-GEOMAR are therefore process studies. Here we are also only at the beginning of understanding Arctic environmental mechanisms. Direct investigations near the ice edge of the polynyas are planned for an upcoming winter expedition in April 2011.

Background information:

The joint Russian-German project "Laptev Sea Polynya" focuses on Arctic front and polynya systems in the Laptev Sea, Siberia, the response of these systems to climate changes, and feedback mechanisms affecting global climate. The project involves multidisciplinary investigations, namely remote sensing, meteorology, oceanography, physics, hydrochemistry, biology, paleoceanography, and climate modelling. It is funded by the German Federal Ministry of Education and Research and the Russian Ministry of Education and Science.

Links:

www.ifm-geomar.de/go/polynja : Laptev Sea Polynya project

References:

Bauch, D., J. Hölemann, S. Willmes, M. Groeger, A. Novikhin, A. Nikulina, H. Kassens, and L. Timokhov, 2010: Changes in distribution of brine waters on the Laptev Sea shelf in 2007. *J. Geophys. Res.*, **115**, C11008, doi:10.1029/2010JC006249.

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